Effects of disk tillage on soil condition, crop yield and weed infestation

M. Birkás, T. Szalai, C. Gyuricza, M. Gecse, K. Bordás

Institute of Crop Production, Szent István University, Gödöllő, Hungary

ABSTRACT

This research was instigated by the fact that during the last decade annually repeated shallow disk tillage on the same field became frequent practice in Hungary. In order to study the changes of soil condition associated with disk tillage and to assess it is consequences, long-term tillage field experiments with different levels of nutrients were set up in 1991 (A) and in 1994 (B) on Chromic Luvisol at Gödöllő. The effects of disk tillage (D) and disk tillage combined with loosening (LD) on soil condition, on yield of maize and winter wheat, and on weed infestation were examined. The evaluation of soil condition measured by cone index and bulk density indicated that use of disking annually resulted in a dense soil layer below the disking depth (diskpan-compaction). It was found, that soil condition deteriorated by diskpan-compaction decreased the yield of maize significantly by 20 and 42% (w/w), and that of wheat by 13 and 15% (w/w) when compared to soils with no diskpan-compaction. Averaged over seven years, and three fertilizer levels, the cover % of the total, grass and perennial weeds on loosened soils were 73, 69 and 65% of soils contained diskpan-compaction.

Keywords: disk tillage; soil loosening; soil compaction; diskpan; maize; winter wheat; weed management

Disk tillage in Hungary can be characterised by four different terms. In the first term (1890–1940), which lasted for half of a century, disks became general and were fitted into cultivation systems. The second term (1950–1960), are years of disk tillage criticism. During the third term (1964–1988) disk tillage became a reasonably economical method. The fourth distinct term dates from 1989 when disking has been often used method despite of the unfavourable soil conditions, because of the economic-pressure Birkás (1998).

From the point of view of agronomy and energy, disking becomes disadvantageous when it is used in unfavourable soil moisture conditions (Birkás 1987, Jóri 1998). Some damages caused by disks are visible, while others can be proven by soil condition tests. Because of the slipping of diskplates, compaction occurs below the depth of the disking, and this damage can happen more frequently on wet soils (Birkás 1987, Spoor 1991).

Diskpan-compaction symptom has been identified only for ten years in the soil tillage literature (Birkás 1987, Birkás et al. 1989). Diskpan-compaction develops because of the repeated disking at same depth even on just wet soil. The diskpan can be thickened if it has not loosened through (Birkás et al. 1998a, Gyuricza and Farkas 1998, Rátonyi and Nagy 1999). Diskpan-compaction was measured on 16% of 2580 ha examined area between 1991–1997, however 12% of this area was compacted below the disk-pans (Birkás et al. 1998b). Since the maximum depth of disking is 20 cm, the diskpan-compaction is more damaging to the soil than the ploughpan-compaction. The rooting depth of crops is decreased, and this compacted layer restricts the water infiltration and prolongs flooding in the fields during wet seasons (Birkás et al. 1997).

One of the aims of the tillage research between 1960–1990 was to study effects of shallow, ploughless tillage (mainly disking) on yield. The results showed the applicability of disk tillage under winter cereals (Sipos 1972, 1973). Similar results were presented with maize (Kismányoky and Balázs 1996, Nagy 1996, Fenyves 1997), supporting that the depth and method of tillage do not significantly effect the yield of maize on well-structured soils. Current soil tillage research examines the tillage effects on soil condition, as a requirement of sustainable crop production (Suškevič 1995, Birkás et al. 1997, Kováč 1998, Lacko-Bartošová and Košovan 1998, Rátonyi and Nagy 1999). A question of alleviating the diskpan by loosening, and qualifying the soil loosening impacts on soil condition posed by Jolánkai et al. (1997), Škoda and Bureš (1998) and Hoffmann (1999), is investigated in this study. The next question to evaluate the disking and loosening effects on weed infestation is also investigated. Weed research proved the disadvantages of disking versus ploughing, but also proved the advantages of it versus zero tillage (Rifai et al. 1996, Birkás et al. 1997).

MATERIAL AND METHODS

The experiments commenced in the autumn of 1991 (A) and 1994 (B), at the crop production farm of the university. The aim of our experiments was to construct models of yearly repeated tillage at the same depth and to examine their effects on the soil condition. In this paper the yearly repeated D is compared with LD. The main purpose of the study is the examination of agronomical effects of the continuous tillage at the same depth on three areas as follows: 1. effect on soil condition, 2. relation between yield and soil condition, 3. soil condition effect on weed infestation.

The crop sequence used in trial A between 1992–1998 was as follows: maize – maize – maize – winter wheat – maize – winter wheat – maize. The rotation used in trial B between 1995–1998 was: maize – winter wheat – maize – winter wheat. Maize is a crop sensitive to soil condition while winter wheat is less sensitive. Both experiments were arranged in stripes with three replications. Trial B was parallel to A thus gave more information about both crops in every year.

Details of treatments used between 1992–1998 on the examined maize and winter wheat plots (the date of primary tillage was the beginning of autumn) are as follows:

Soil tillage:

D = disking (16–20 cm)
LD = loosening (35–40 cm) + disking (16–20 cm)

Fertilizers: F_1 = without fertilizer (control)
F_2 = 80 kg N + 45 kg P_2O_5 + 75 kg K_2O per ha
F_3 = 160 kg N + 90 kg P_2O_5 + 150 kg K_2O per ha

Doses of fertilizers in treatment F_2 are low, and higher in F_3. Weed control after sowing of maize was done once by herbicide followed by a mechanical treatment. Herbicide was used once to control weed in winter wheat.

The experiment was set up on a brown forest soil (Chromic Luvisol) which is a sandy-loam. Clay content of the surface soil (0–35 cm) is 36.0% and water infiltration is good, however it is bad in the subsoil. The soil pH value is 7.1 (KCl). Humus content of the surface soil is 1.17%, which is quite poor. Total amount of N = 0.15%, P_2O_5 = 145 mg.kg^{-1}, K_2O = 150 mg.kg^{-1} (P, K by ammonium lactate method). Years of 1992 and 1993 were dry, 1994, 1996 and 1997 were average and 1995 and 1998 were wet.

Examinations of soil condition was done by Niekrashoff-type cartridge method in 0–50 cm depth till 1996, by Dvoracsek-type penetrometer at the depth of 0–65 cm from 1994 and by PENETRONIK-type penetrometer of Szarvas (Daróczi and Lelkes 1999) from 1995 at the depth of 0–70–75 cm. For measuring of weed infestation Ujvárosi method based on estimation of ground cover % was adopted. Statistical analysis was done according to Sváb (1981).

RESULTS AND DISCUSSION

Changes in soil condition

Changes of soil condition were measured continuously in the experiments from the beginning. In trial A results concerning 1st, 3rd, 5th and 6th years are presented in Figure 1 and Table 1. Soil condition was favourable to

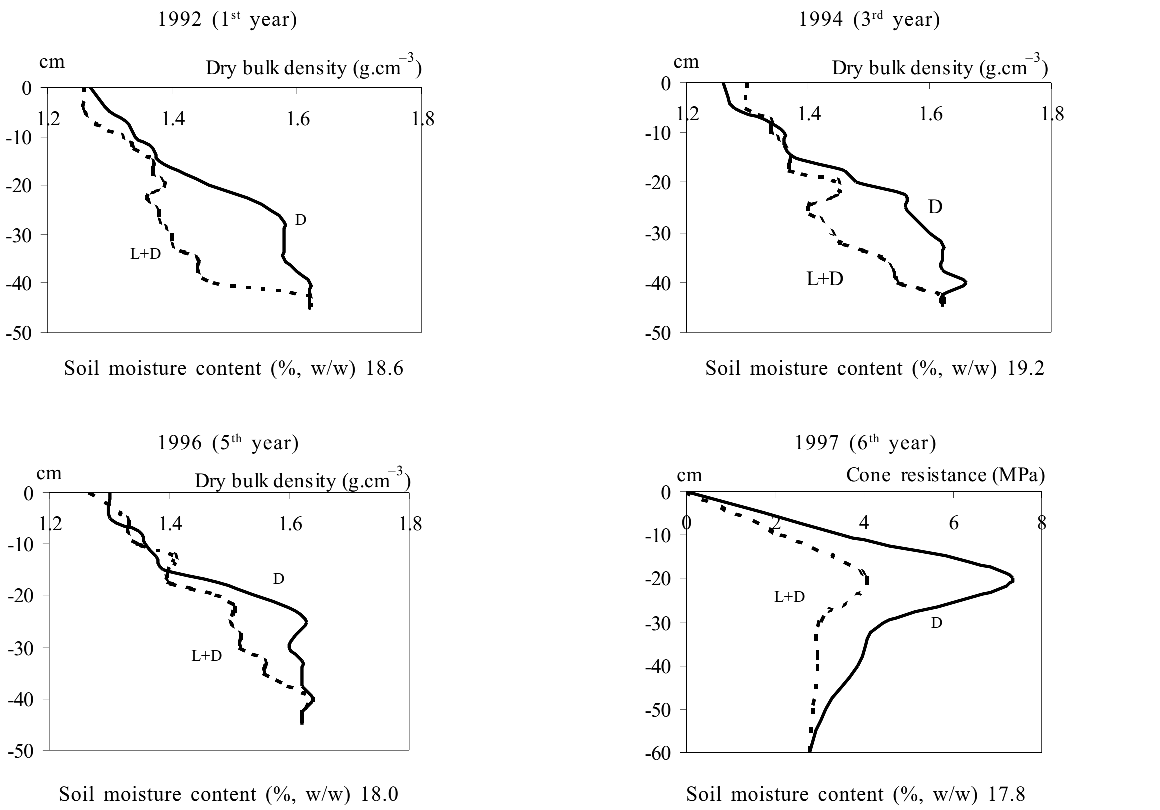

Figure 1. Effects of the yearly repeated disking and the loosening combined with disking on soil condition (Gödöllő, 1992–1997); L + D = loosening + disking 35–40 cm, D = disking 16–20 cm

Table 1. Extension of the soil compaction as the effect of the annually repeated disk tillage at a depth of the disking and below disking during five vegetation periods, experiment A (Gödöllő 1992–1996)

Soil layer (cm)	D 16–20 cm			LD 35–40 cm		
	1st yr. (1992)	3rd yr. (1994)	5th yr. (1996)	1st yr. (1992)	3rd yr. (1994)	5th yr. (1996)
15.0–17.5	≤ 1.38	≤ 1.38	≤ 1.38	≤ 1.38	≤ 1.38	1.39–1.45
17.5–20.0	1.39–1.45	1.39–1.45	1.46–1.53	≤ 1.38	≤ 1.38	1.39–1.45
20.0–22.5	1.39–1.45	1.46–1.53	1.54–1.60	1.39–1.45	1.39–1.45	1.46–1.53
22.5–25.0	1.46–1.53	1.54–1.60	1.61–1.64	1.39–1.45	1.39–1.45	1.46–1.53
25.0–27.5	1.54–1.60	1.54–1.60	1.61–1.64	1.39–1.45	1.39–1.45	1.46–1.53

Dry bulk density of soil ($g.cm^{-3}$): ≤ 1.38, 1.39–1.45, 1.46–1.53, 1.54–1.60, 1.61–1.64

a depth of tillage during the vegetation periods. However, the curve of compaction of disk tilled soil increases down to 20 cm. Below this layer the curve reaches the value of 1.6 $g.cm^{-3}$, which is unfavourable for crop production. A more precise illustration of the improving of diskpan-compaction (defined in the introduction) is shown in Table 1. It was found, that a yearly repeated D causes thickening of compacted layer, and this extends both to the surface and to deeper layers. Aftermaths of this process is demonstrated both in harvest results and weed infestation. Penetration resistance values recorded in autumn of 1997 follow the tendencies of the previous year. Diskpan-compaction reached the value of 8 MPa, which is rather unfavourable.

Effects of LD in the upper 20 cm layer is similar to simple D so can be expected changes below this layer. Soil condition of 20–40 cm layer was most favourable in the first year of experiment. It was found that duration of the loosening effects on a given soil lasted only for one vegetation period or even shorter (Gyuricza and Farkas 1998). In the 20–22 cm layer was a re-compacting effect of the surface D in the third and fifth years was observed. Soil strength of LD at the disked layer reached the maximum 4 MPa and that was 33% more compacted than the deeper layers.

The relationship between soil condition and yield

Yield of maize is shown in Tables 2 and 3. In the seven years experiment A, maize was grown on the field for five years. The average yield during this period on D treatment was very low at 2.16 $t.ha^{-1}$. The level of yield, typical for this region (3.5–4.0 $t.ha^{-1}$), was reached only in 1996 and with high level of nutrient supply. It is likely, that yearly repeated shallow D on soil sensitive to settling is not suitable for maize-growing. In experiment B, shallow D with crop rotation and with adequate rainfall – two years results indicate suitability for maize-growing to the end of the third vegetation period.

Table 2. The D and LD effects on maize yield on three fertilization levels, experiment-A (Gödöllő 1992–1998)

Soil tillage	Fertilization NPK ($kg.ha^{-1}$)	Yield ($t.ha^{-1}$)					
		1992 (1st yr.)	1993 (2nd yr.)	1994 (3rd yr.)	1996 (5th yr.)	1998 (7th yr.)	mean
Disking (D)	control	2.11	1.15	0.72	2.16	1.58	1.54
	200	2.76	1.29	1.51	3.02	2.12	2.14
	400	2.81	1.51	2.70	4.09	2.87	2.78
	mean	2.56	1.32	1.64	3.09	2.19	2.16
Loosening	control	2.35	2.29	1.86	4.10	4.51	3.04
combined	200	3.27	2.74	2.26	4.99	5.50	3.75
disking (LD)	400	3.66	3.21	2.40	5.67	6.06	4.31
	mean	3.09	2.75	2.17	4.92	5.39	3.70
LSD_5%	tillage (1)	0.587	0.264	0.246	0.934	0.555	1.458
	fertilization (2)	0.102	0.235	0.242	0.545	0.183	0.352
	T × F (1 × 2)	0.396	0.285	0.292	0.626	0.442	ns
F-test *p*%	tillage (1)	10	1	10	5	0.5	5
	fertilization (2)	0.5	0.5	0.5	1	0.5	0.5
	T × F (1 × 2)	5	5	1	5	1	ns

ns = non significant

Table 3. The D and LD effects on maize yield on three fertilization levels, experiment B (Gödöllő 1995–1997)

Soil tillage	Fertilization NPK (kg.ha^{-1})	Yield (t.ha^{-1})		
		1995 (1st yr.)	1997 (3rd yr.)	mean
Disking (D)	control	3.65	2.61	3.13
	200	5.08	3.05	4.07
	400	5.78	3.41	4.60
	mean	4.84	3.02	3.94
Loosening combined disking (LD)	control	5.34	3.11	4.22
	200	6.27	3.71	4.99
	400	6.94	4.19	5.57
	mean	6.18	3.67	4.93
LSD_5%	tillage (1) fertilization (2) T × F (1 × 2)	5.188	0.408	5.402
		1.55	0.148	1.406
		ns	ns	ns
F-test p%	tillage (1) fertilization (2) T × F (1 × 2)	ns	5	ns
		10	0.5	10
		ns	ns	ns

Using LD, the average of yield for five years was 3.70 t.ha^{-1}. In case of proper rainfall the yields in trial A – in every level of fertilization and in trial B – in two maize growing years with one exception exceeded the average yield typical of this region. The effect of fertilizer on the yield was significant in both cases and in every year. Between the two tillage methods, in every year of trial A and in one year of trial B (1995), significant difference could be found.

In trial A, the average yield of D was 42% lower than the average yield of LD. Noticeable, that the difference between the yields of two methods was the lowest (17%) at the beginning of the experiment (1992), when there were not great differences between soil condition. The difference was higher (52–59%) between dry and wet vegetation periods. The difference between two methods without fertilizers was higher (49%) during five years, however application of fertilizers lowered this difference. On high level of nutrient supply the yield reached by D was 35% lower, than by LD. Trial B follows the same tendency. Similar data could be found in literature (Győrffy 1990, Nagy 1996, Drimba and Nagy 1998).

Yields of winter wheat from A and B are presented in Table 4. In this region with conventional tillage methods and almost favourable nutrient supply, 2.5–3.0 t.ha^{-1} winter wheat yield can be reached. The summarised average

Table 4. The D and LD effects on the winter wheat yield on three fertilization levels, experiments A and B (Gödöllő 1995–1998)

Soil tillage	Fertilization NPK (kg.ha^{-1})	Yield (t.ha^{-1})				
		experiment A		experiment B		mean
		1995 (4th yr.)	1997 (6th yr.)	1996 (2nd yr.)	1998 (4th yr.)	
Disking (D)	control	2.58	2.24	0.70	1.14	1.66
	200	3.53	2.68	1.93	2.98	2.77
	400	4.91	3.54	1.85	3.98	3.57
	mean	3.67	2.82	1.49	2.70	2.67
Loosening	control	3.45	2.79	0.89	1.37	2.13
combined	200	3.85	3.64	2.03	3.56	3.27
disking (LD)	400	5.10	4.33	1.99	4.93	4.09
	mean	4.13	3.59	1.64	3.29	3.16
LSD_5%	tillage (1)	0.613	0.514	0.671	0.362	0.417
	fertilization (2)	0.262	0.516	1.399	0.443	0.906
	T × F (1 × 2)	ns	ns	ns	ns	ns
F-test p%	tillage (1)	10	5	ns	5	5
	fertilization (2)	0.5	1	10	0.5	1
	T × F (1 × 2)	ns	ns	ns	ns	ns

Table 5. Cover % of weeds in maize used D annually (in average of three fertilization levels)

Weed groups	Trial A				Trial B	
	1st year	3rd year	5th year	7th year	1st year	3rd year
Total	10.55	14.55	3.35	42.74	1.90	8.02
Grass	3.89	7.29	1.34	33.13	0.06	5.47
Perennial	2.10	3.03	2.58	29.73	1.07	1.06
Summer	8.19	11.11	0.77	10.03	0.43	6.94

of the trials achieved this level both in case of D and LD. Increase of fertilizers in every case resulted in significant yield increase, and tillage also caused yield increase except one year (1996). The difference between years was less than in case of maize but the best year was the wettest vegetation period of 1995. The yields of D was 16% lower than the yields by LD in the averages of years and fertilizer levels. The difference in trial A, where compaction was below the disked layer, is 16% and 13% in trial B. Finally, it was found that the yearly repeated shallow D on a given soil is unfavourable, even for growing winter wheat, which is tolerant to the soil condition.

Relations between soil condition and weed infestation

The weed infestation results of maize and winter wheat are discussed separately. Their vegetation periods are different and other weed population can be expected according to literature (Buhler 1992, Buhler et al.1994, Albrecht and Sommer 1998). The data of weed infestation of maize, detailed by groups of weeds are summarised in Tables 5 and 6.

The total cover of weeds increased four times in both areas, in trial A it reached that point in the 7th year, and in trial B in the 4th year. The relapse occurred in the 5th year. As a result of rotation with winter wheat, the increase of summer weeds covering in trial A was 22%. Over the years perennial weed cover increased, main weed was perennial ryegrass (*Lolium perenne* L.) which was not sensitive to diskpan-compaction.

Total cover of weeds in maize increased five times in trial A by the 7th year, and four times in trial B by the 3rd year. The cause in the latter case was probably the ploughless tillage and much more precipitation (Buhler 1992, Gallagher and Cardina 1998). The increase summer weeds cover was nearly doubled by the 7th year and nine times more in case of grass-weeds. Summer weeds cover in trial B was similar to that in trial A until the 3rd year.

Similar tendencies but different rates can be observed between covering of weeds under two methods of non-inversion primary tillage. Weed cover % of the areas were balanced at the beginning of the trial, but were changed during the first vegetation period to advantage of LD. This advantage remained until the 7th year of the experiment. In the 7th year, when tillage loosened deeper layers, total % cover weeds was 73% of D. Grass-weed covering was 69% lower, perennial weed covering was 65% lower than in case of simple D. Weed limiting effect of LD can also be proven in every group of trial B during three years. Although this is not equal to the weed control effect of regular ploughing, but it contributes to more impartial, wider view of soil loosening (Birkás et al. 1997, Birkás et al. 1998a, Gallagher and Cardina 1998).

We were managing the weed cover using winter wheat phases during the longer period of trial A and the shorter period of trial B (Table 7). In trial A wheat production with D also resulted significant decrease in weed infestation, for example total coverage decreased 20 times. Weed infestation in trial B increased from the 2nd till the 4th year, but neither the total coverage reaches the critical level. Weed infestation tendencies of two non-inversion tillage are similar according to the results. The data of weed coverage of the first year growing winter wheat are different, mainly in trial A. In case of LD the weed cover of every group of weeds is lower than in case of D. It is especially prominent in respect of summer and total weed coverage. It is also important that loosening is a considerable method for restricting the vitality of perennial weeds, since it was the 4th year without ploughing in

Table 6. Cover % of weeds in maize used LD annually (in average of three fertilization levels)

Weed groups	Trial A				Trial B	
	1st year	3rd year	5th year	7th year	1st year	3rd year
Total	6.10	8.82	1.80	31.05	1.69	6.29
Grass	2.59	5.25	0.99	22.99	0.02	3.41
Perennial	0.42	1.38	1.30	19.22	0.42	0.85
Summer	5.56	7.35	0.50	10.88	1.00	5.19

Table 7. Cover % of weeds in winter wheat used D and LD annually (in average of three fertilization levels)

Weed groups	D				LD			
	trial A		trial B		trial A		trial B	
	4th year	6th year	2nd year	4th year	4th year	6th year	2nd year	4th year
Total	19.08	0.89	2.21	3.62	8.42	1.29	1.96	3.02
Grass	7.08	0.27	0.06	0.37	4.33	0.51	0.19	0.52
Perennial	3.67	0.58	0.54	0.77	2.17	0.77	0.42	0.78
Summer	13.67	0.21	0.38	0.50	6.08	0.26	0.54	0.60

trial A. The advantages of weed controlling role of soil loosening was also found between the 2nd and 4th year of trial B.

At the end results can be summarised as follows. According to experiments it was found, that yearly repeated shallow disk tillage caused compaction at the depth of tillage after the 3rd year both in dry, average and wet years. Thickening of the compacted layer was observable both in surface and deeper layers from the 5th year.

Disk tillage combined with loosening proved to be a favourable soil conservation method. Between two non-inversion tillage methods, the loosening effect was more favourable for maize and winter wheat production, considering a longer period. As soil condition gets poorer – mainly in dry and wet years – shallow disk tillage by the diskpan-compaction, becomes a factor of yield reduction.

Soil condition – caused by shallow disk tillage – increase weed infestation in maize, and in case of maize and winter wheat cropping sequence. The weed managing effect of annually repeated loosening in maize and in winter wheat was found, and this contributes to impartial, complex view of soil loosening.

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ABSTRAKT

Vliv zpracování půdy talířovými podmítači na stav půdy, výnos plodin a zaplevelení

V maďarském zemědělství se v posledním desetiletí příliš často používá opakované mělké zpracování půdy talířovým nářadím. S cílem zjistit změny půdních vlastností v důsledku této technologie zpracování půdy a vyhodnotit jejich následky byly v Gödöllő (Chromic Luvisol podle kategorizace FAO) v roce 1991 (A) a v roce 1994 (B) založeny dlouhodobé polní pokusy s diferencovaným hnojením. Byl sledován vliv talířového zpracování (D) a talířového zpracování v kombinaci s kypřením dlátovými kypřiči (LD) na půdní vlastnosti, na výnos kukuřice a ozimé pšenice a na zaplevelení porostů. Změny půdních vlastností, hodnocené na základě penetračního odporu a objemové hmotnosti půdy, naznačily, že pravidelné zpracování půdy s využitím talířového nářadí má za následek narůstající zhutňování vrstvy půdy pod hloubkou zpracování, adekvátní zhutnělému podbrázdí, které je typické pro konvenční kultivaci zahrnující orbu. Dále bylo zjištěno, že dochází ke statisticky významnému snížení výnosu zrna u kukuřice o 20 až 42 % a u ozimé pšenice o 13 až 15 % v porovnání s variantami na půdách, kde se zhutnění ve zmíněných horizontech nevyskytuje. V průměru sedmi let a při třech hladinách hnojení byla celková pokryvnost jednoděložných a víceletých plevelů na půdách zpracovaných kypřiči do větších hloubek pouze 73, 69 a 65 % ve srovnání s půdami zpracovávanými jen talířovým nářadím.

Klíčová slova: zpracování půdy talířovými a dlátovými kypřiči; zhutnění půdy; výnosy zrna; kukuřice; ozimá pšenice; zaplevelení porostů

Corresponding author:

Dr. Márta Birkás, Institute of Crop Production, Szent István University, H-2103 Gödöllő, Hungary, tel.: + 36 28 42 20 00, fax: + 36 28 41 08 04, e-mail: sun@fau.gau.hu